Rate of carbonate formation in Saskatchewan soils, Canada

Ahmad Landi[1]; A. R. Mermut[2] ,and D.W.Anderson[3]

[1] Department of Soil Science, College of Agriculture, University of Saskatchewan. Saskatoon, Saskatchewan, Canada. Landi@saska.usask.ca

[2] Department of Soil Science, College of Agriculture, University of Saskatchewan. Saskatoon, Saskatchewan, Canada. Mermut@saska.usask.ca

[3] Department of Soil Science, College of Agriculture, University of Saskatchewan. Saskatoon, Saskatchewan, Canada.

Introduction

Evaluating the magnitude of the pedogenic inorganic carbon (PIC) pool and its dynamics is important for understanding the carbon pools and fluxes between the atmosphere, biosphere and the pedosphere (Lal et al., 2000). Soil organic carbon (SOC) and inorganic carbon (SIC) or pedogenic carbonates, estimated to be 2500 Pg, which is the third largest global carbon pool (after oceanic 39,000 Pg and geologic 5,000 Pg), plays an important role in the global carbon cycle. Because of the complexity of processes involved in atmosphere-vegetation-soil-landscape-subsurface, there are only a few reliable estimates of the pool of secondary carbonates in the world's soil, and of the long-term net carbon fluxes from atmosphere to the soil (Lal et al., 2000). Estimates of global soil inorganic carbon (SIC) or pedogenic carbon (PC) reported to be between 800 Pg and 1730 Pg. Differences among the estimates are probably due to the inability to differentiate between the presence of primary carbonate (carbonitic rock fragments) in soils and carbonate of secondary origin. To enhance the application of current and future models on carbon fluxes, the size of the carbon pool must be established and the dynamics of this pool evaluated (IPCC, 1996, Legros et al., 1994). The stable isotope method is the only reliable technique used to estimate the amount of current pedogenic carbonate. The basis of this method is that carbon in lithogenic carbonate has a significantly different isotopic composition than that in pedoginic carbonate.

Study Area

In Saskatchewan, ecosystems at macro-scale are largely related to climatic zones, reflecting the effect of latitude and diminishing energy gradient from the southwest to the northeast. In no other part of Canada are the zonal relationships between climate, soils and distribution of native species, so clearly displayed, from the warmer (but still cool), dry native grasslands of the southwest through the cool, moist parkland area, to the cold, dry lichen woodlands in the northeast (Acton et al., 1998). History of deglaciation is well established in the Canadian prairies, by using the deglaciation history we can estimate the fine ellipsoid for soil formation at any spot in Saskatchewan and consequently calculate the rate of formation of pedogenic carbonate for each soil zone. Ice margin position map is used to estimate the age of each site.

Material and methods

Soils are sampled on well-drained level to gently sloping upper slope, in order to minimize the influence of lateral redistribution of carbonate (i.e., in an environment where a moderate, but dominantly descending mode of soil moisture is prevalent). Soils formed on glacial till parent materials were utilized for the study. Three replicates from each zone (in major soil associations), for a total of 15 profiles, were sampled. Two replicates in the vicinity of each profile were added to establish the degree of variability. Soil profiles were dug up to include parent material in each site and described in detail. Where present, pebbles with pedogenic carbonate (carbonate pendant) were collected.

Bulk soils were ground and passed through a 60-mesh sieve. Then samples were treated with Sodium Hypochlorite 5.25% (bleach) to remove organic matter. Treated samples were powdered and analyzed for $\delta^{13}C$ and $\delta^{18}O$ ratios, using a Thermo-Quest-Finnigan-GasBench-II instrument and a continuous flow method. Pendants (pure carbonates) were powdered and analyzed for $\delta^{13}C$ and $\delta^{18}O$ ratios, using the same method. Bulk soils with enough organic carbon (more than 0.3%) were treated with 3 M HCl to remove carbonates where they were present. Then samples were analyzed for $\delta^{13}C$ ratio using the continuous flow stable isotope mass spectrometry method to find out the relationship between organic matter and carbonate formation. The amount of pedogenic carbonate is calculated from carbon isotopic composition (Salomons and Mook, 1976):

$$\%\ \text{Pedogenic carbonates} = \frac{\delta^{13}C\ (\text{soil}) - \delta^{13}C\ (\text{p.m.})}{\delta^{13}C\ (\text{new}) - \delta^{13}C\ (\text{p.m.})} \times 100$$

Results and Discussion

Primary results show that the $\delta^{13}C$ ratio of organic matter decreases (become more negative) from southwestern (warmer and drier part) to northeastern (cooler and more moister part) of Saskatchewan, which suggest a changes from more grass and C4 plants to more trees and C3 plants (Fig.1).

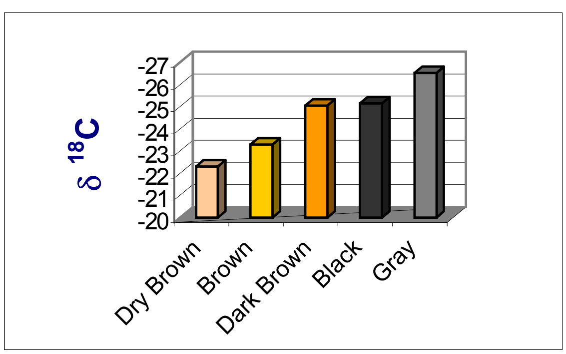

Fig.1. Stable isotope ratio of organic matter

The $\delta^{13}C$ ratios of carbonates suggest that they are formed from the oxidation of organic matter. The amount of pedogenic carbonate increases from southwest to northeast Saskatchewan (Fig.2), despite the fact that the expousre time of parent material for soil formation decreases towards the northeastern direction. The rate of carbonate formation is shown in Figure 3.

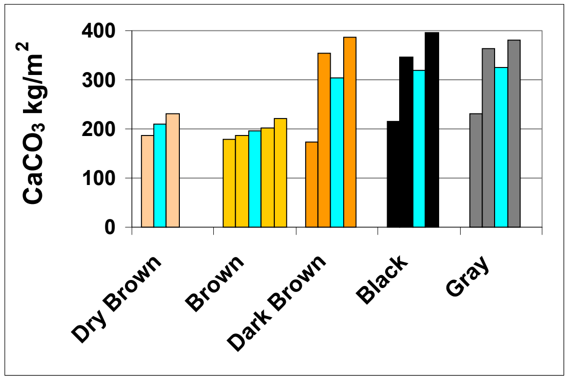

Fig.2. The amount of carbonate in different soil zones

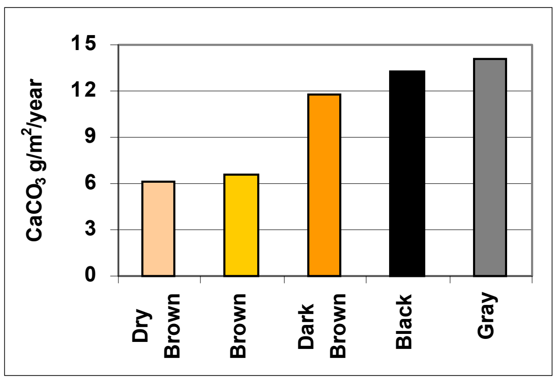

Fig.3. Rate of carbonate formation

The results show that despite the shorter exposure time for soil formation, the amount and the rate of carbonate formation increases from southwest to northeast. This has an important implication for the re-estimation of the amount of secondary carbonates in the world prairie soils

References

Acton, D.F.; Padbury, G.A., and C.T. Stushnoff. 1998. The ecoregions of Saskatchewan. Canadian Plains Research Center/Saskatchewan Environment and Resource Management.

IPCC. 1996. Climate change 1995. Impacts, Adaptation, and Mitigation of climate Change: Scientific-Technical Analyses. R.T. Watson, M.C. Zinyowera, and R.H. Moss (eds) Publ. for the Intergovernmental Panel on Climate Change (IPCC), Cambridge Univ. Press. 878 pp.

Lal, R.; J.M. Kimble; H. Eswaran, and B.A. Stewart, 2000. Golbal climate change and pedogenic carbonates. CRC Press LLC. USA.

Legros, J.P., P.J. Loveland, and M.D.A. Rounsevell. 1994. Soils and climate change- Where next? p 258-266. In: M.D.A. Rounesvell and P.J. Loveland (eds.), Soil Response to Climate Change. NATO ASI Series Vol. 23, Springer-Verlag, Berlin.

Salomons, W., and W.G. Mook. 1976. Isotope geochemistry of carbonate dissolution and reprecipitation in soils. Soil Sci. 122: 15-24.